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(54) **PROGRAMMABLE INTEGER AND
FRACTIONAL FREQUENCY DIVIDER**

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H03K 23/00 (2006.01)

(52) **U.S. Cl.** **377/47; 377/48**

(58) **Field of Classification Search** None
See application file for complete search history.

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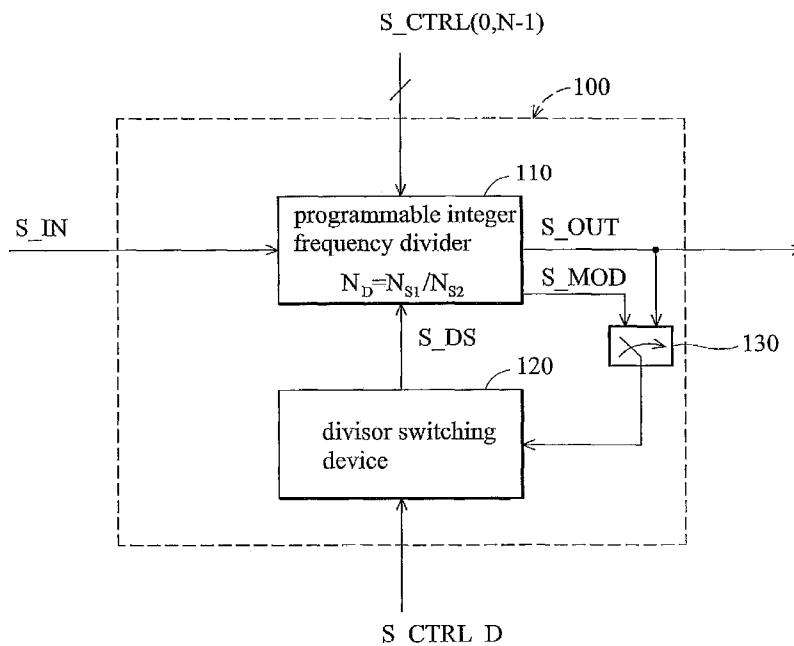
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(57) **ABSTRACT**

A programmable integer and fractional frequency divider is provided. The programmable divider divides a frequency of an input signal by a first divisor to generate an output signal, and comprises a programmable integer frequency divider and a fractional number switch. The programmable integer frequency divider divides the frequency of the input signal by a second divisor to generate the output signal, wherein the second divisor is first or second integers depending on a divisor switching signal. The fractional number switch calculates a pulse count of the output signal, and generates the divisor switching signal to switch from the first to the second integer when the pulse count of the output signal equals to a predetermined pulse count determined by a fractional part of the first divisor, and receives a fractional divisor control signal to change the predetermined pulse count, thereby changing the fractional part of the first divisor.

18 Claims, 9 Drawing Sheets



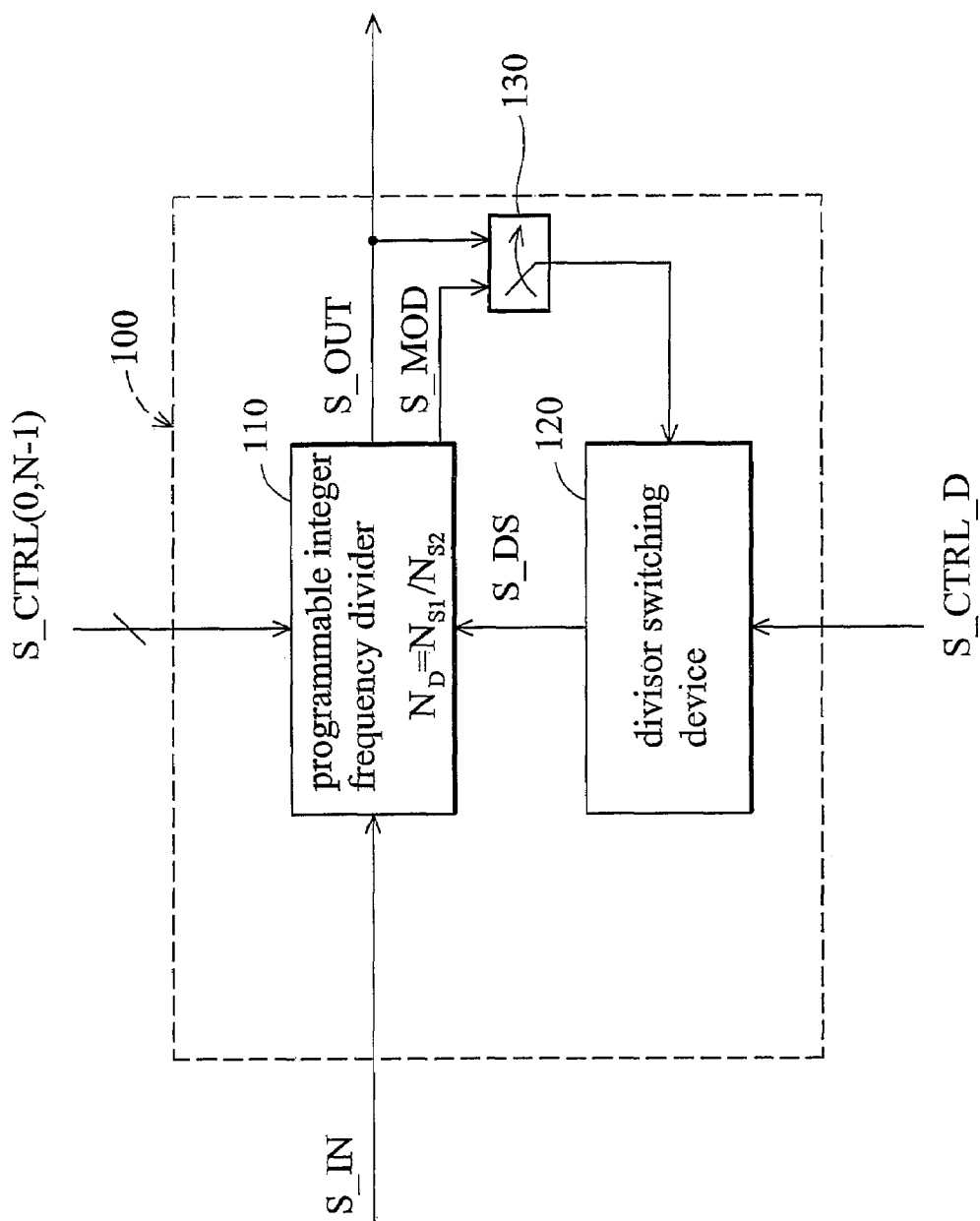


FIG. 1

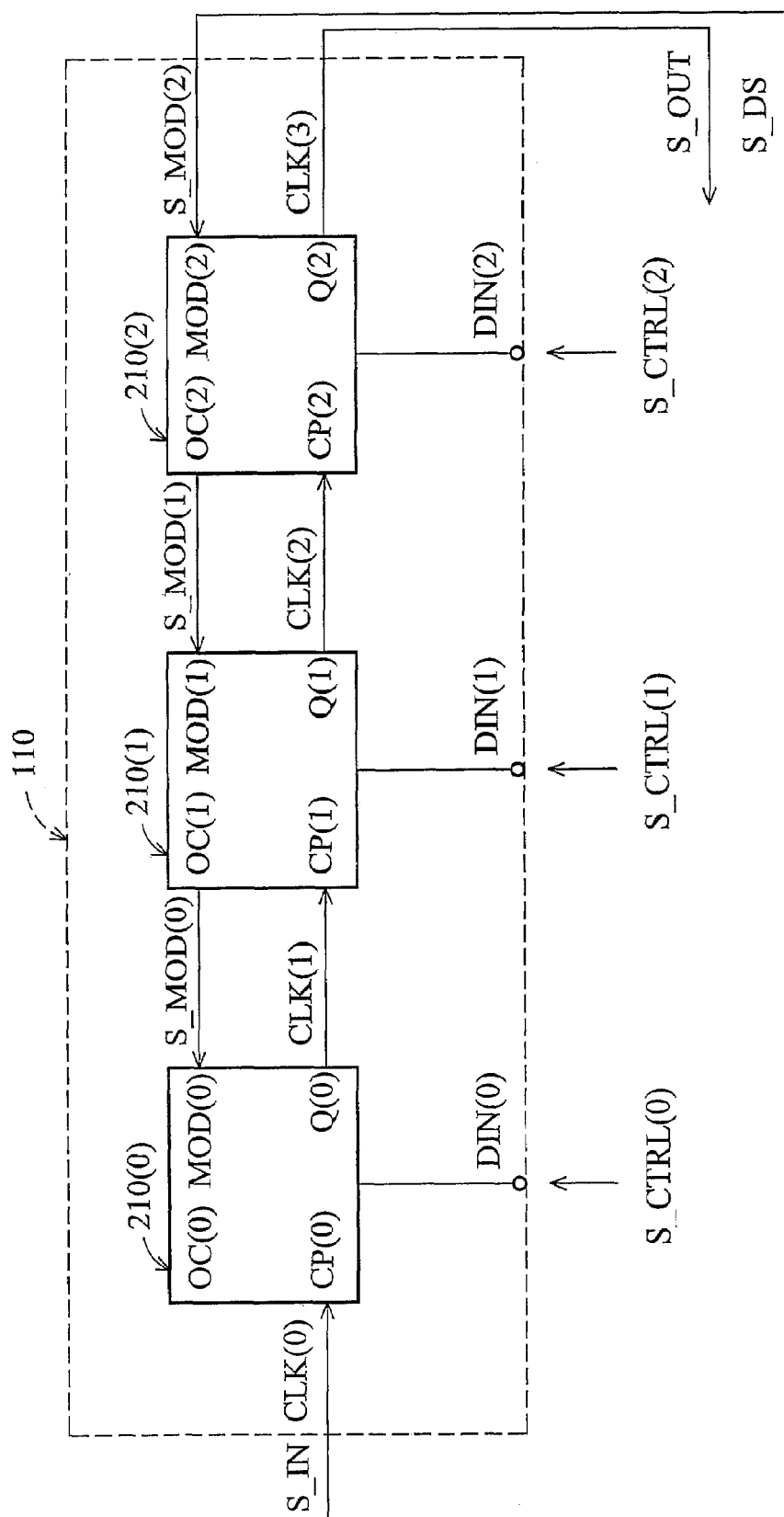
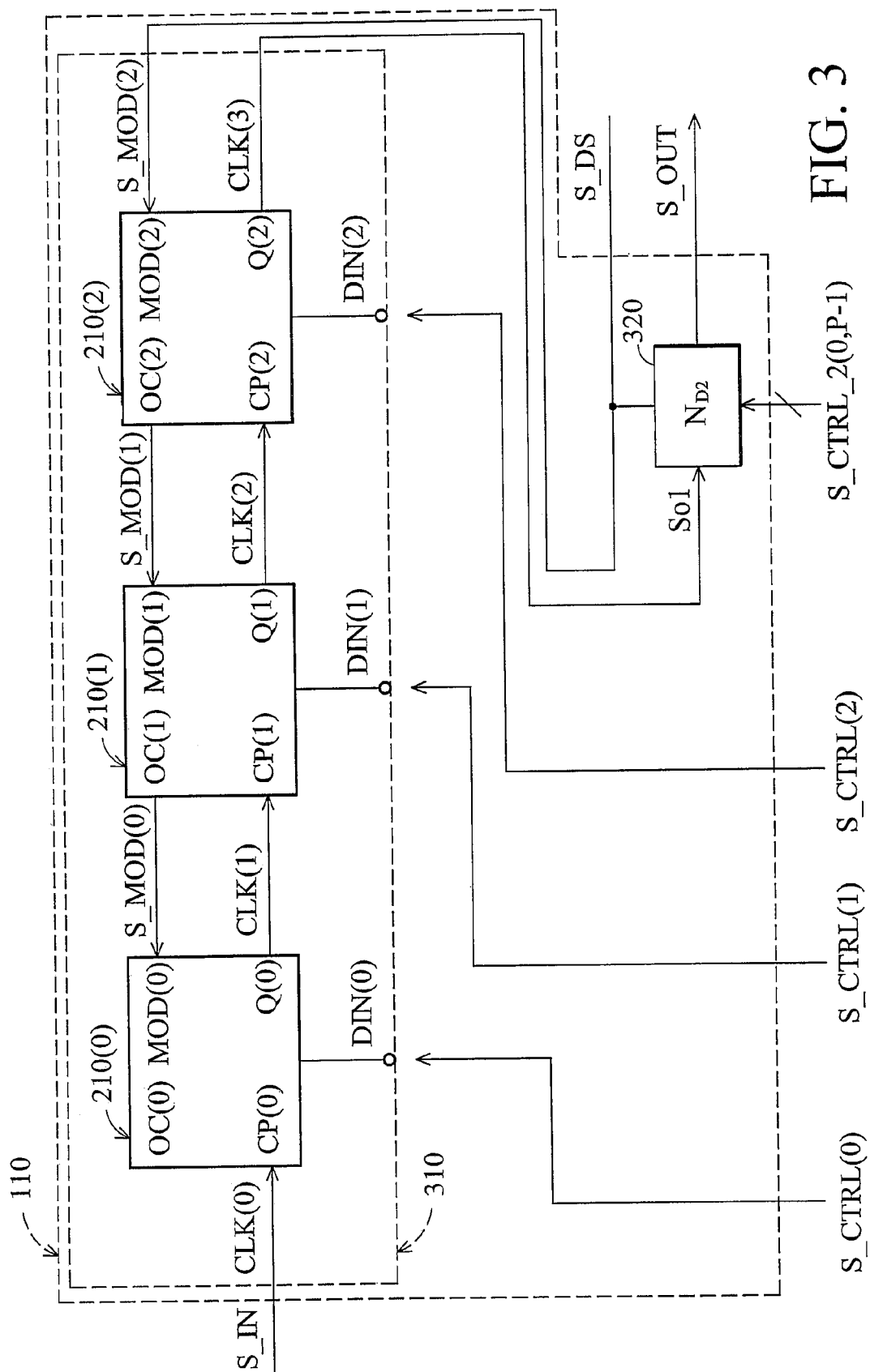


FIG. 2



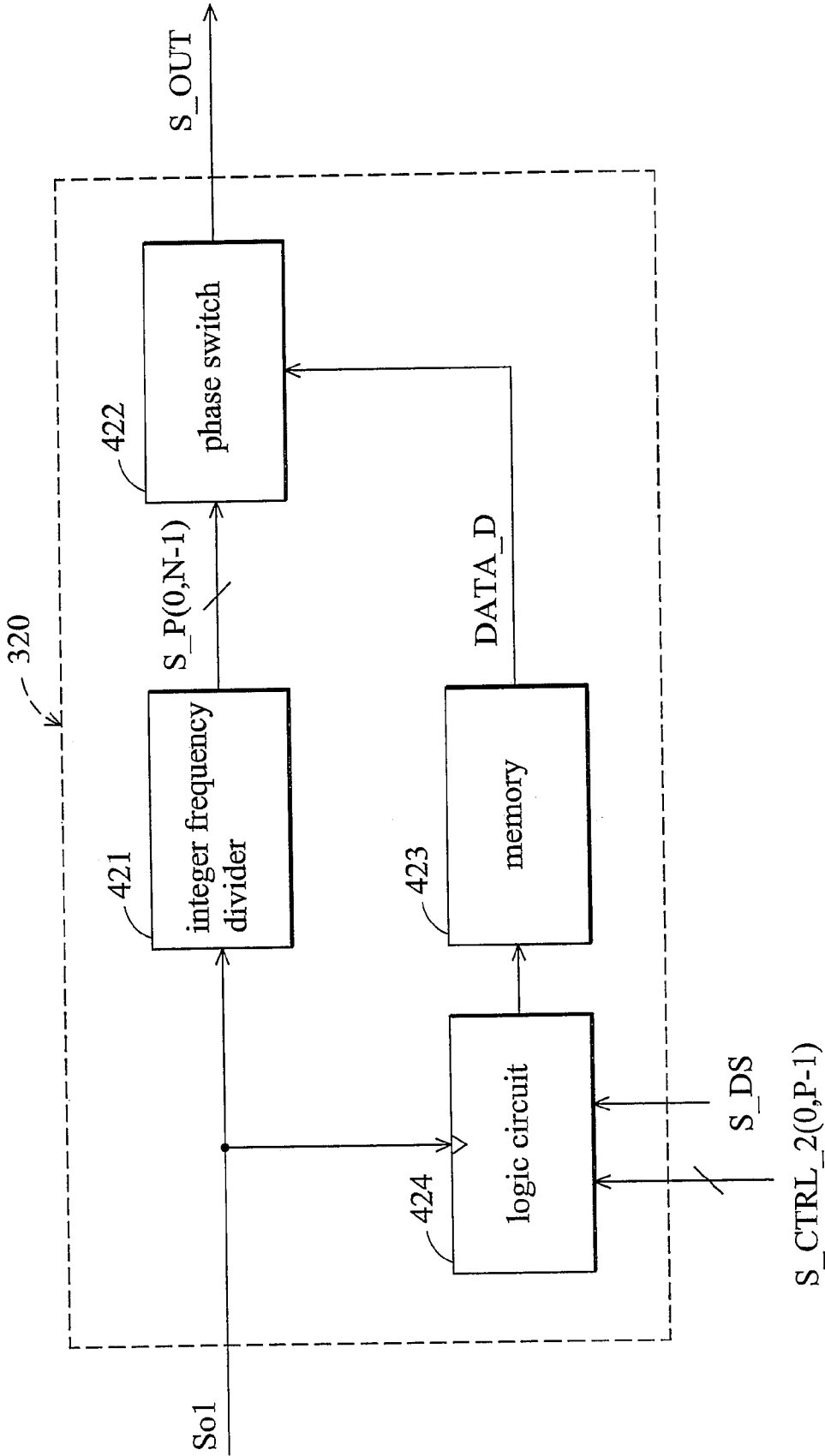


FIG. 4

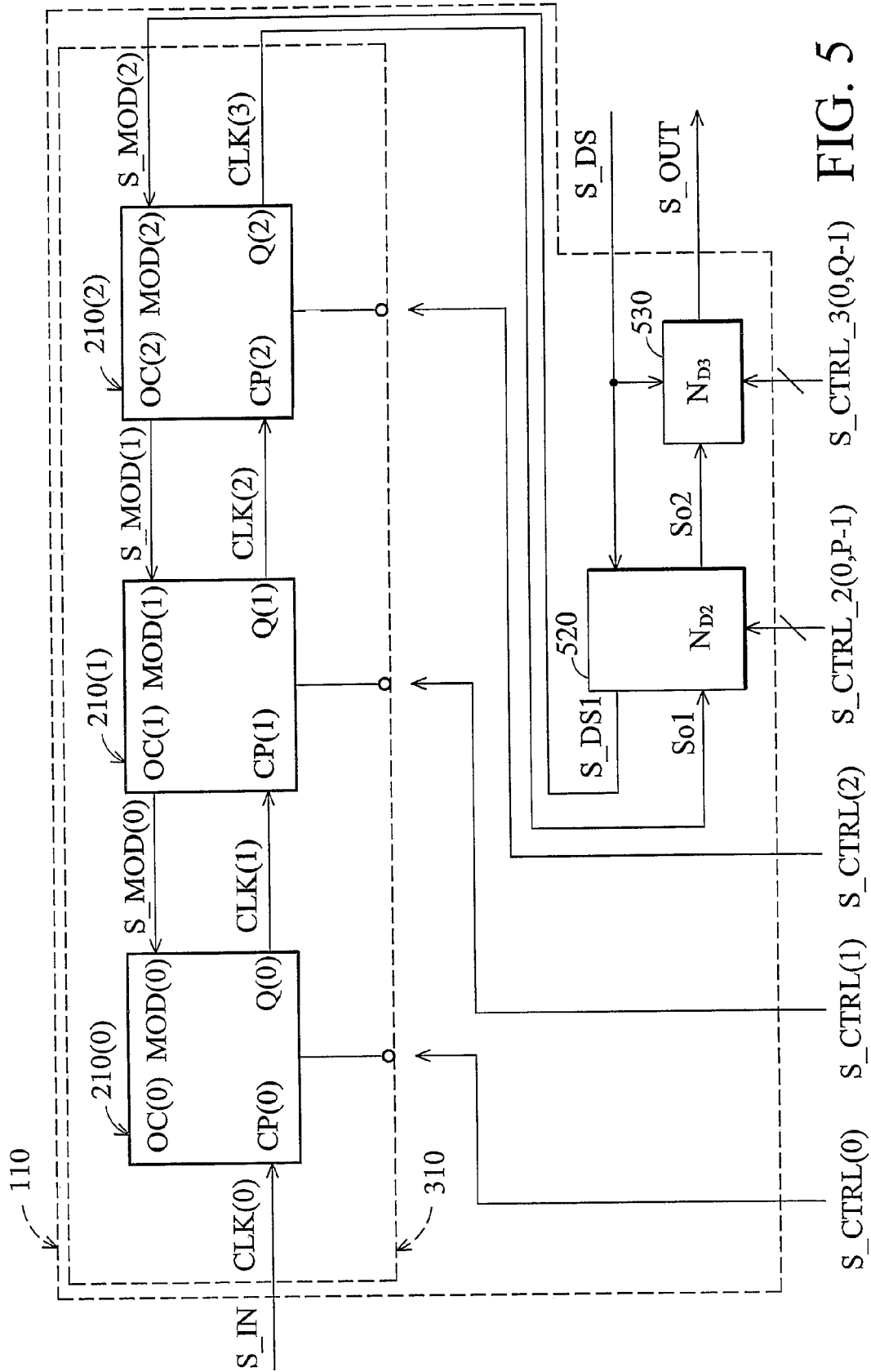


FIG. 5

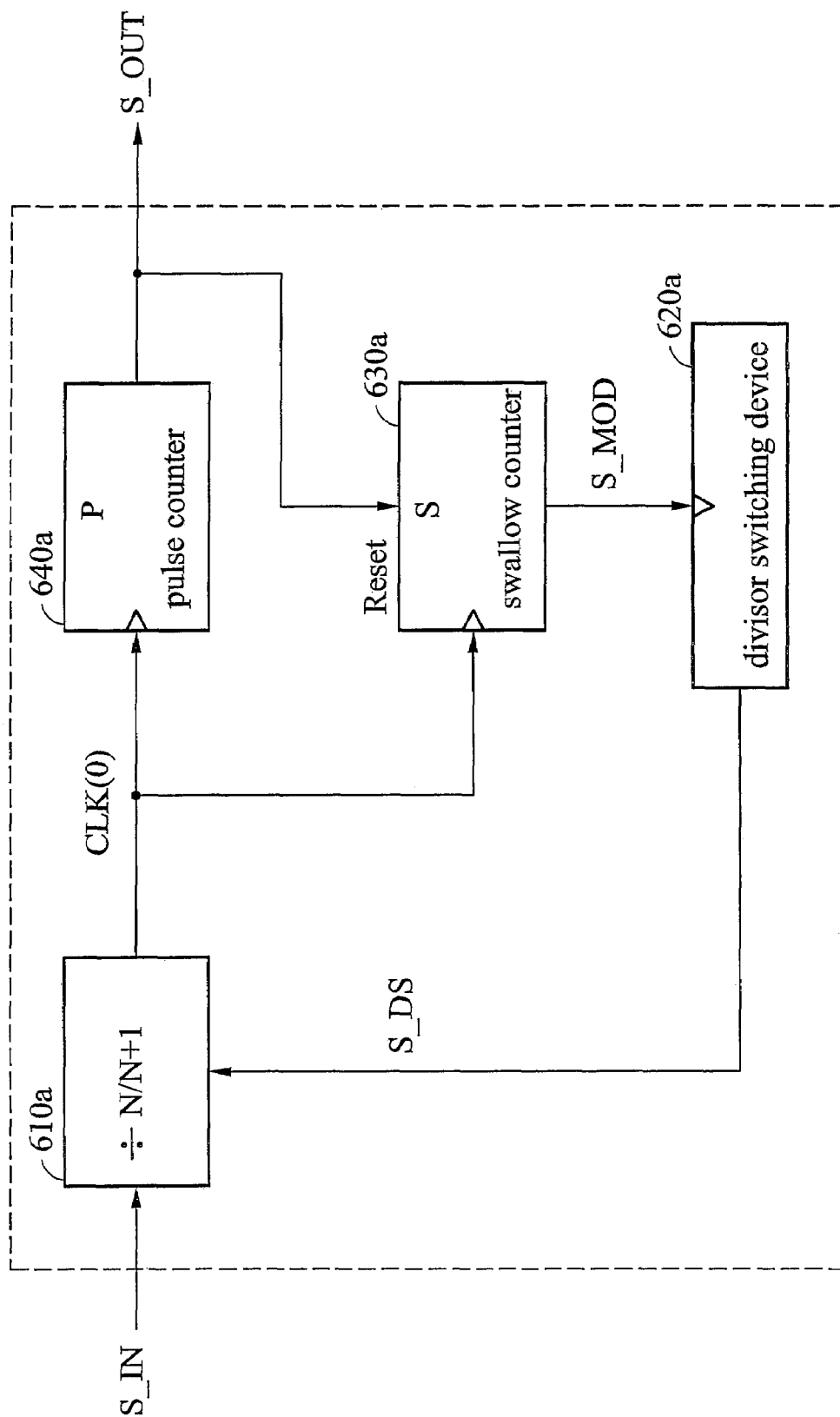


FIG. 6a

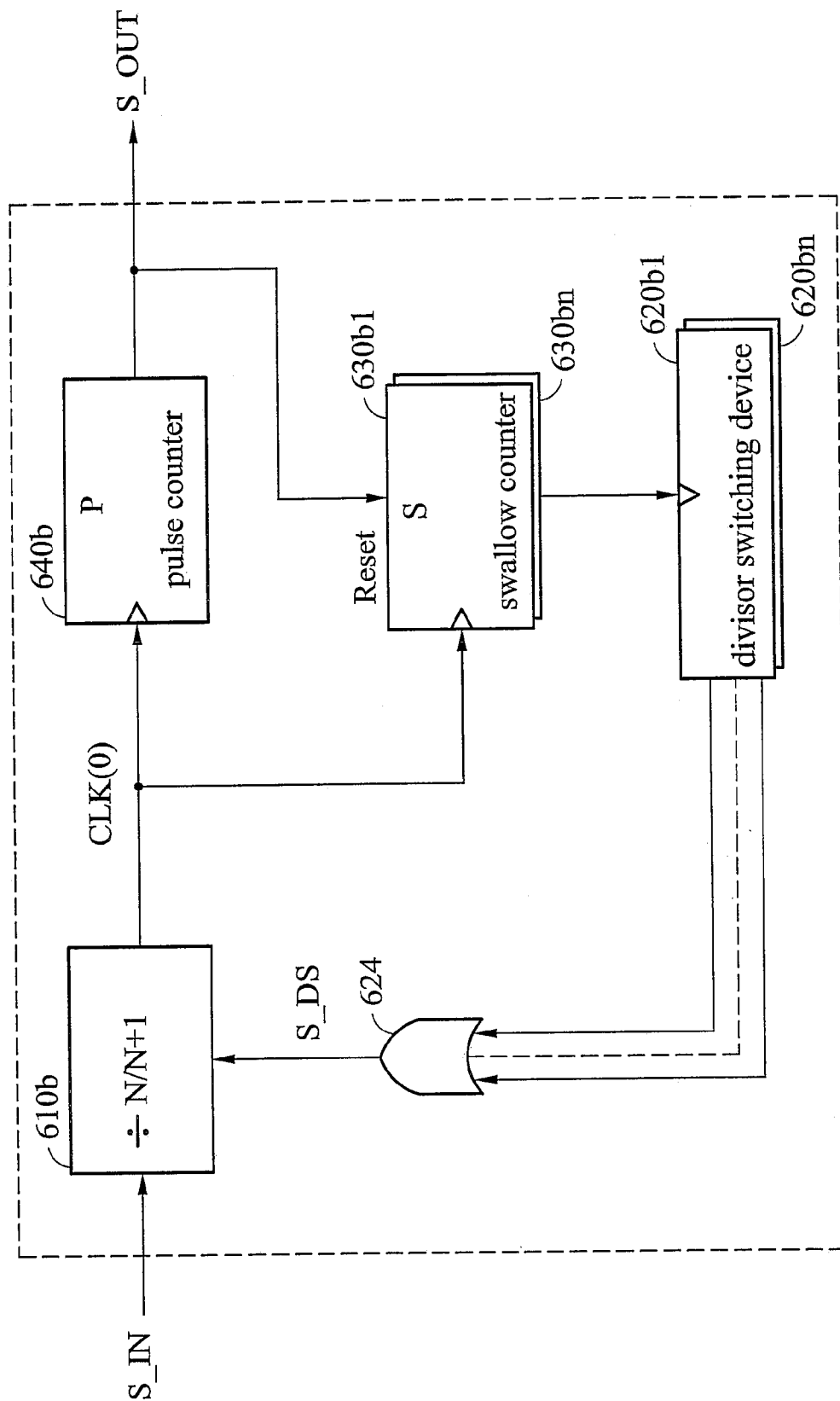


FIG. 6b

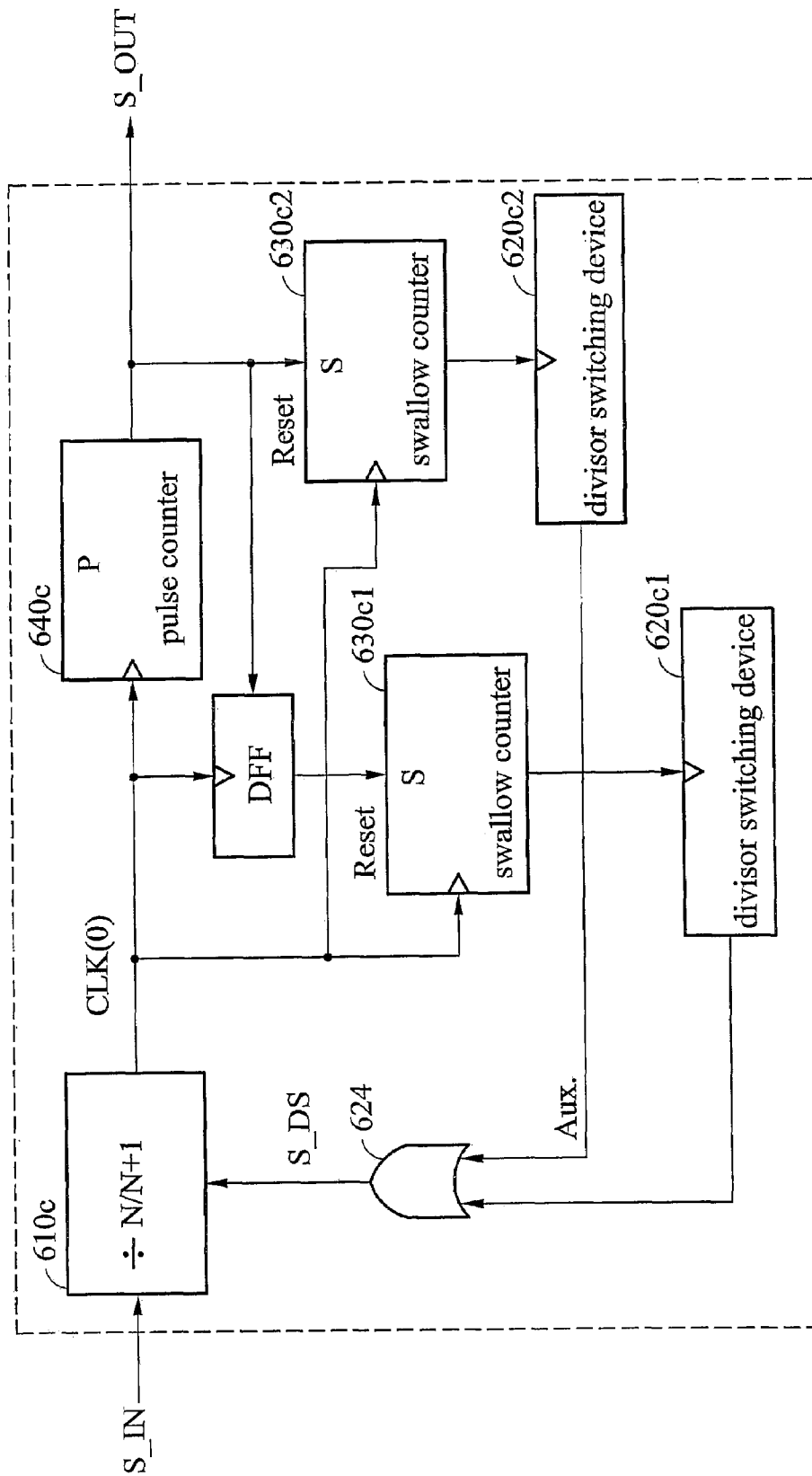


FIG. 6c

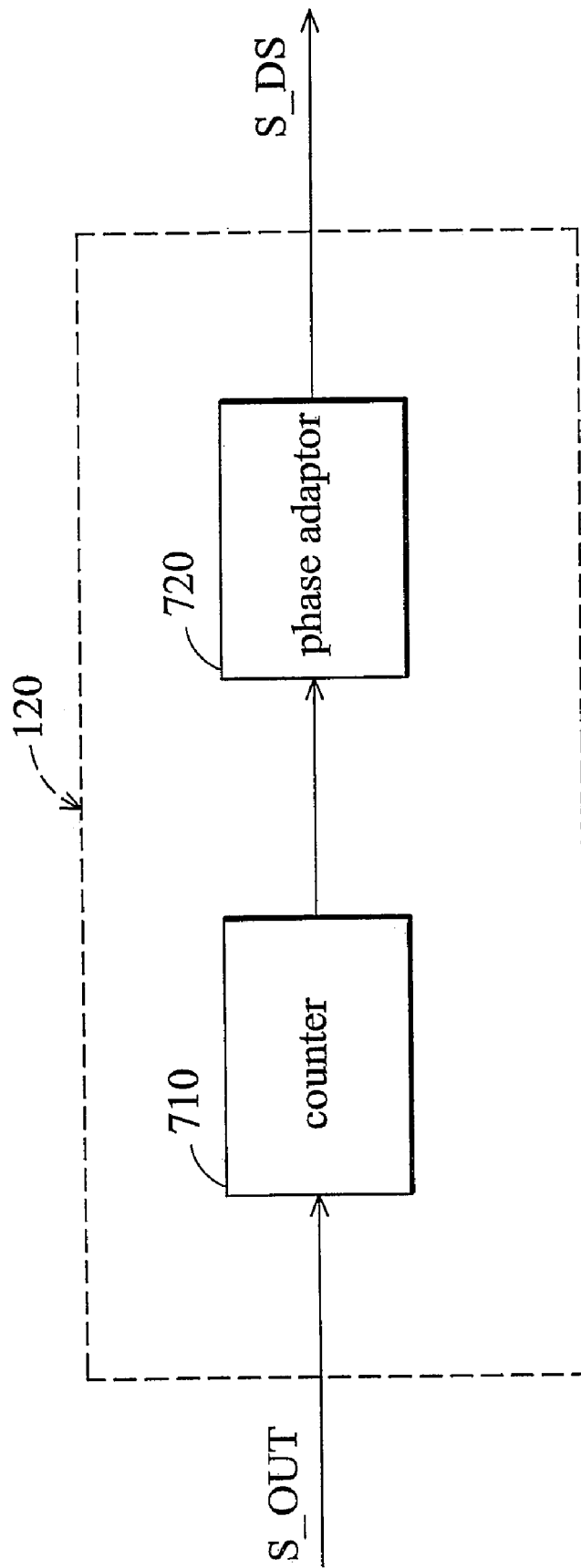


FIG. 7

1

PROGRAMMABLE INTEGER AND FRACTIONAL FREQUENCY DIVIDER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to programmable frequency dividers, and in particular to programmable integer and fractional frequency dividers.

2. Description of the Related Art

Conventionally, a device performing frequency division of a high frequency signal, dividing a high input frequency to a desirable output frequency, is known as a programmable frequency divider or direct programmable frequency divider.

At present, programmable frequency dividers are accomplished by two approaches. The first approach is a frequency divider with a pulse/swallow counter. The frequency divider utilizes a dual-modulus divider, a programmable counter, and a swallow counter to provide the functionality of integer programmable frequency divider. The advantage is that the circuit design is adaptive to operational division range. The disadvantages are that only integer division is allowable, and that the dual-modulus divider is used in multi-mode or multi-band, thus, dissipating much power, and resulting in the frequency divider being unable to provide optimal power distribution to the three utilized circuits under a fixed method.

The second approach utilizes a multi-mode fractional frequency divider, for example, a divide-by-2/2.5/3/3.5 cell, coupled to a zipper frequency divider. The multi-mode frequency divider uses a state machine to control phase switching to provide divisors. The zipper frequency divider comprises multiple dual-modulus division cells coupled in series, each a divide-by-2/3 cell. The advantage is that the frequency divider is capable of fractional division. However, high frequency circuit design remains a challenge owing to the state machine utilized in the multi-modulus divider. The state machine utilized in the multi-modulus divider and other circuits are designed according to the fractions in uses, thus, the fraction choices are limited. Further, since the minimal divisor for the zipper frequency divider is 2^N , N is the number of dual-modulus dividing cells, the divisors in the programmable frequency divider are limited, leading to a requirement of more dual-modulus dividing cells for the operational divisor range.

BRIEF SUMMARY OF THE INVENTION

A detailed description is given in the following embodiments with reference to the accompanying drawings.

According to an embodiment of the invention, a programmable integer and fractional frequency divider is disclosed, dividing a frequency of an input signal by a first divisor to generate an output signal, wherein the first divisor is an integer or a fraction, and the programmable integer and fractional frequency divider comprises a programmable integer frequency divider and a fractional number switch. The programmable integer frequency divider divides the frequency of the input signal by a second divisor to generate the output signal, wherein the second divisor is set to be first or second integers according to a divisor switching signal. The fractional number switch, calculates a pulse count of the output signal, and generates the divisor switching signal to switch from the first integer to the second integer when the pulse count of the output signal equals to a predetermined pulse count, wherein the predetermined pulse count is determined by a fractional part of the first divisor, and the fractional number switch

2

receives at least a fractional divisor control signal to change the predetermined pulse count, thereby changing the fractional part of the first divisor.

Also provided is a programmable integer and fractional frequency divider, dividing a frequency of an input signal by a first divisor to generate an output signal, wherein the first divisor is an integer or a fraction. The programmable integer and fractional frequency divider comprises a dual-modulus divider, a programmable counter, a swallow counter and fractional number switch. The dual-modulus divider divides the frequency of the output signal by a second divisor, wherein the second divisor is first or second integers according to a divisor switching signal. The programmable counter calculates a pulse count of the output signal of the dual-modulus divider, and generates the output signal when the pulse count equals to a third integer. The swallow counter, calculates the pulse count of the output signal of the dual-modulus divider, switches a mode signal to a second level when the output signal equals to a fourth integer, and resets the mode signal to a first level when the output signal is a predetermined level. The fractional number switch calculates a pulse count of the mode signal of the swallow counter, generates the divisor switching signal to switch a divisor of the dual-modulus divider when the pulse count of the mode signal equals to a predetermined pulse count, wherein the predetermined pulse count is determined by a fractional part of the first divisor, and the fractional number switch receives at least one fractional divisor control signal to change the predetermined pulse count, thereby changing the fractional part of the first divider.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention can be more fully understood by reading the subsequent detailed description and examples with references made to the accompanying drawings, wherein:

FIG. 1 is a block diagram for an exemplary programmable integer and fraction frequency divider according to the invention.

FIG. 2 is an exemplary circuit diagram of a programmable integer frequency divider **110** in FIG. 1.

FIG. 3 is another exemplary circuit diagram of a programmable integer frequency divider **110** in FIG. 1.

FIG. 4 is a block diagram of an exemplary programmable frequency divider.

FIG. 5 is a block diagram of an exemplary programmable integer frequency divider **110** in FIG. 1.

FIG. 6a, b, and c are block diagrams of another exemplary programmable integer and fraction frequency divider **100** in FIG. 1.

FIG. 7 is a block diagram of an exemplary fractional number switch **120**.

DETAILED DESCRIPTION OF THE INVENTION

The following description is of the best-contemplated mode of carrying out the invention. This description is made for the purpose of illustrating the general principles of the invention and should not be taken in a limiting sense. The scope of the invention is best determined by reference to the appended claims.

FIG. 1 is a block diagram for an exemplary programmable integer and fraction frequency divider **100** according to the invention. The programmable integer and fraction frequency divider **100** divides input frequency f_{IN} by Z to produce $f_{OUT}=f_{IN}/Z$, wherein divisor Z is an arbitrary integer or a fractional number.

Typically, the minimal value of the fractional number of the frequency divider is determined by a preceding circuit (not shown) providing input frequency f_{IN} . For example, when the preceding circuit comprises a frequency divider dividing a higher output frequency by predetermined divisor N_P to generate input frequency f_{IN} , the minimal value of the fractional number is selected as $1/N_P$ to reduce phase noise effect. For example, when predetermined divisor N_P is 2 or 4, the minimal value of the fractional number is 0.5 or 0.25. In most frequency divider applications, output frequency f_{OUT} is provided, so that integer N is determined by input frequency f_{IN} , and $f_{IN}/Z=f_{OUT}$.

As shown in FIG. 1, programmable integer and fraction frequency divider **100** comprises programmable integer frequency divider **110**, switch **130**, and fractional number switch **120** coupled to programmable integer frequency divider **110**. Programmable integer frequency divider **110** is coupled to switch **130**.

Divisor N_D of the programmable integer frequency divider **110** is determined by first integer N_{S1} and second integer N_{S2} , wherein at least one is set to be divisor N_D by default. Programmable integer frequency divider **110** receives input signal S_{IN} having input frequency f_{IN} , divides input frequency f_{IN} by divisor N_D , and outputs output signal S_{OUT} having $f_{OUT}=f_{IN}/N_D$. While performing the division, programmable integer frequency divider **110** also receives at least one divisor switching signal from fractional number switch **120**, e.g., divisor switching signal S_{DS} in FIG. 1, and determines switching divisor N_D according to divisor switching signal S_{DS} . In one embodiment, divisor switching signal S_{DS} may be a first level or a second level, and programmable integer frequency divider **110** may set divisor N_D to be integers N_{S1} and N_{S2} , accordingly.

Please note that, in one embodiment, divisor switching signal S_{DS} of programmable integer frequency divider **110** is only determined by the divisor switching signal of fractional number switch **120**.

Switch **130** controls the connection between programmable integer frequency divider **110** and fractional number switch **120**. When using zipper architecture, switch **130** switches to output signal S_{OUT} , when using pulse/swallow counter architecture, switch **130** switches to mode signal S_{MOD} .

Fractional number switch **120** receives mode signal S_{MOD} and output signal S_{OUT} , calculates the pulse count in output signal S_{OUT} , and generates divisor switching signal S_{DS} according to the pulse count and mode signal S_{MOD} . In one embodiment, divisor switching signal S_{DS} is set as the first level in advance to set divisor N_D by N_{S1} . When the pulse count of output signal S_{OUT} equals to a predetermined pulse count (N_P-1), fractional number switch **120** switches divisor switching signal S_{DS} from the first to the second levels, so that divisor N_D can switch from integers N_{S1} to N_{S2} . Using the pulse count of output signal S_{OUT} , the level of divisor switching signal S_{DS} returns to the first level to keep divisor N_D at integer N_{S1} . As indicated in FIG. 1, fractional number switch **120** receives fractional divisor control signal S_{CTRL_D} generated by an external circuit (not shown) to control predetermined divisor N_P , thereby controlling the minimal value of the fraction number. The advantage of this approach is by properly designing programmable integer frequency divider **110**, any fractional divisor may be obtained through controlling predetermined divisor N_P .

The time for divisor Z and divisor switching signal S_{DS} remaining at the second level, i.e., the pulse width of divisor switching signal S_{DS} , is determined by predetermined divisor N_P , integers N_{S1} and N_{S2} . Assuming divisor N_D has a

predetermined value N_{S1} and the pulse width of divisor switching signal S_{DS} is that of output signal S_{OUT} , input signal S_{IN} must be $N_P Z$ pulses for programmable integer and fraction frequency divider **100** to generate N_P pulses in output signal S_{OUT} . During $N_P Z$ pulse generation, input signal S_{IN} is divided by integer N_{S1} during the first (N_P-1) pulses, and then divided by N_{S2} during the last pulse. Thus $N_P \times Z = N_{S1} \times (N_P-1) + N_{S2} \times 1$, and $Z = N_{S1} \times (N_P-1) / N_P + N_{S2} / N_P$. Similarly, when the pulse width of divisor switching signal S_{DS} is X times that of output signal S_{OUT} , divisor $Z = [N_{S1} \times (N_P-1) / N_P + N_{S2} / N_P] \times X$.

FIG. 2 is an exemplary circuit diagram of a programmable integer frequency divider **110** in FIG. 1. As shown in FIG. 2, programmable integer frequency divider **110** is a zipper divider comprising N ($N=3$ in the embodiment) programmable dual-modulus dividing cells **210(0)** to **210(2)** coupled in series.

Each dual-modulus dividing cell **210(k)** comprises a clock input terminal $CP(k)$ for receiving signal $CLK(k)$, a mode input $MOD(k)$ for receiving $S_{MOD}(k)$, a clock output $Q(k)$ for outputting signal $CLK(k+1)$, and mode output $OC(k)$ coupled to each other as indicated in FIG. 2. Each dual-modulus dividing cell **210(k)** also comprises divisor control terminal $DIN(k)$ coupled to divisor control signal $S_{CTRL}(k)$ provided by an external circuit (not shown). Input signal S_{IN} is provided to clock input terminal $CP(0)$ of dual-modulus dividing cell **210(0)** for signal $CLK(0)$, and $CLK(N)$ of clock output $Q(N-1)$ of the last dual-modulus dividing cell **210(N-1)** is the output signal S_{OUT} of programmable integer frequency divider **110**. Divisor switching signal S_{DS} generated by fractional number switch **120** is mode signal $S_{MOD}(N-1)$ of the last dual-modulus dividing cell **210(N-1)**.

The divisor of each dual-modulus dividing cells **210(k)**, defined by frequency of signal $CLK(k+1)$ /frequency of signal $CLK(k)$, is 2 or 3, and divisor N_D of programmable integer frequency divider **110** can be represented by:

$$N_D = 2^N + (D_{N-1} \times 2^{N-1} + \dots + D_1 \times 2^1 + D_0 \times 2^0)$$

Where divisor coefficient D_k is 0 or 1, determined by divisor control signal $S_{CTRL}(k)$ received by divisor control terminal $DIN(k)$ and mode signal $S_{MOD}(k)$.

While the divisor of each dual-modulus dividing cell can be changed to 2 or 3 in the embodiment, $N1$ and $(N1+1)$ can also be used for the divisors. $N1$ is not limited at 2, and those with ordinary skill in the art can make appropriate modifications. Divisor Z of programmable integer frequency divider **110** can be represented by:

$$N_D = N1^N + (D_{N-1} \times 2^{N-1} + \dots + D_1 \times 2^1 + D_0 \times 2^0)$$

Referring to FIG. 1, to ensure the continuous range of all integers, the mode I/O control terminal of the dual-modulus dividing cell is coupled to logical circuits with appropriate modifications. The disclosures of a zipper divider can be found in U.S. Pat. No. 5,065,415, U.S. Pat. No. 6,281,721, "A low-power truly modular 1.8 GHz programmable divider in standard CMOS technology" by C. Vaucher and Z. Wang in ESSCIRC'99, pp. 406-409, 1999, and "A family of low-power truly modular programmable dividers in standard 0.35- μ m CMOS technology" by C. Vaucher, I. Ferencic, M. Locher, S. Sedvallson, U. Voegeli, and Z. Wang in IEEE J. Solid-State Circuits SC-35, No. 7, pp. 1039-1045, 2000, respectively.

When divisor switching signal S_{DS} is the first level (high level) or the second level (low level), the divisor of programmable integer frequency divider **110** is $N_{D1}=N1^N$ or

5

$N_{D2}=N1^N+(D_{N-1}\times 2^{N-1}+\dots +D_1\times 2^1+D_0\times 2^0)$. Thus fractional number switch **120** sets the fractional number as $1/N_P$, so that when the pulse width of divisor switching signal S_{DS} equals to that of output signal S_{OUT} , divisor Z is $N_{D1}\times(N_P-1)/N_P+N_{D2}/N_P=N1^N+(D_{N1}\times 2^{N-1}+\dots +D_1\times 2^1+D_0\times 2^0)/N_P$.

Note programmable integer frequency divider **110** in FIG. **1** may comprise at least one frequency divider coupled in series, so long as at least one of the frequency dividers is a programmable integer frequency divider controlled by the fractional number switch for changing the divisor.

FIG. **3** is another exemplary circuit diagram of a programmable integer frequency divider **110** in FIG. **1**. As shown in FIG. **3**, programmable integer frequency divider **110** comprises zipper frequency divider **310** and integer frequency divider **320**. In comparison with FIG. **2**, integer frequency divider **320** is added between the zipper divider (zipper frequency divider **310** in FIG. **3**) and fractional number switch **120**. The circuit components identical to FIG. **2** which have already been explained will not be repeated for brevity.

Integer frequency divider **320** receives output signal $So1$ of zipper frequency divider **310**, i.e., signal $CLK(N)$ generated at clock output $Q(N-1)$, divides signal $CLK(N)$ by divisor N_{D2} to generate output signal S_{OUT} .

When divisor switching signal S_{DS} is the first level (high level) or the second level (low level), the overall divisor of zipper frequency divider **310** and integer frequency divider **320** is $N_{S1}=N1^N\times N_{D2}$ or $N_{S2}=N1^N\times N_{D2}+(2^{N-1}\times DS_{N-1}+2^{N-2}\times DS_{N-2}+\dots +2^0\times DS_0)$. Therefore when fractional number switch **120** sets its fractional number as $1/N_P$, the pulse width of divisor switching signal S_{DS} equals to that of output signal S_{OUT} , $Z=N_{S1}\times(N_P-1)/N_P+N_{S2}/N_P=N_{S1}+(2^0\times DS_0+2^1\times DS_1+\dots +2^{N-1}\times DS_{N-1})/N_P$, where DS_0 to DS_{N-1} are determined by the levels of divisor control signals $S_CTRL(0)$ to $S_CTRL(N-1)$.

Generally speaking, when utilizing programmable integer frequency divider **110** in the embodiment, divisor Z of programmable integer and fractional frequency divider is represented by:

$$Z=N1^N\times N_{D2}+2^{-M}\times DZ_0+2^{-(M-1)}\times DZ_1+\dots +2^{N-M-2}\times DZ_{N-2}+2^{N-M-1}\times DZ_{N-1}$$

The difference between FIG. **3** and FIG. **2** is that the start integer is $N1^N\times N_{D2}$ instead of $N1^N$. In order to obtain divisor Z , the predetermined divisor N_P and signal levels of DZ_0 to DZ_{N-1} are required, where DZ_0 to DZ_{N-1} are determined by $S_CTRL(0)$ to $S_CTRL(N-1)$.

While the pulse count calculated by fractional number switch **120** in FIG. **3** is $1/N_{D2}$ times that of in FIG. **2**, the pulse width of divisor switching signal S_{DS} in FIG. **3** is N_{D2} times that of in FIG. **2**, thus after compensation, the predetermine pulse count for FIGS. **2** and **3** are both $N_P=2^M/X$.

For example, the divisor is set as $Z=26.5$ for a level 3 ($N=3$ and $N1=2$) dual-modulus dividing cell **210**. Since $Z=2^3\times 3+(2^{-1}\times 1+(2^0)\times 0+(2^1)\times 1)$ ($M=1$ and $X=1$), N_{D2} is set to 3, DZ_0 to DZ_{N-1} are set to 1, 0, 1 respectively. Similarly, divisor control signals $S_CTRL(0)$ to $S_CTRL(2)$ are the first level (high level), the second level (low level), the first level (high level), and $N_P=2$.

Integer frequency divider **320** may also be a programmable frequency divider, receiving at least one second divisor control signal, e.g., $S_CTRL_2(0)$ to $S_CTRL_2(P-1)$ in FIG. **3**, to change N_{D2} . In doing so, the lower limit of the divisor range of programmable integer and fraction frequency divider **100** is $2^N\times N_{D2}$, not limited to the base of 2. As a result, fewer cells of zipper dividers (smaller N) can accomplish larger divisor Z .

6

FIG. **4** is a block diagram of an exemplary programmable frequency divider, as a modification of integer frequency divider **320** in FIG. **3**. As shown in FIG. **4**, integer frequency divider **320** is a multi-modulus dividing cell comprising integer frequency divider **421**, phase switch **422**, embedded memory **423**, and logic circuit **424**.

Integer frequency divider **421** receives the output of zipper frequency divider **310**, and divides the output by integer N , e.g., 2, to provide signals $S_P(0)$ to $S_P(N-1)$ with different phases, e.g., 0° or 180° , to a phase input terminal of phase switch **422**. Embedded memory **423** stores at least 2 sets of phase conversion data $DATA_D$ of the divisors, corresponding to different integer divisor N_{D2} . Logic circuit **424** receives at least one second divisor control signal, e.g., $S_CTRL_2(0)$ to $S_CTRL_2(P-1)$ in the diagram and divisor switching signal S_{DS} , and generates the address of embedded memory **423** by the second divisor control signals $S_CTRL_2(0)$ to $S_CTRL_2(P-1)$ and divisor switching signal S_{DS} , instructs embedded memory **423** to provide phase conversion data $DATA_D$ to the phase control terminal of phase switch **422**. Phase switch **422** sequentially determines an output signal as one in signals $S_P(0)$ to $S_P(N-1)$ according to phase conversion data $DATA_D$ of each bit. Each phase conversion data $DATA_D$ represents the divisor, providing integer frequency divider **320** with different divisor N_D , e.g., 3, 4, 5, and 6. Memory **423** may be an embedded memory, phase conversion data $DATA_D$ may be changed anytime after IC manufacturing, thereby changing the divisor range of programmable integer frequency divider **110**.

Please note that the divisor switching signal generated by dual-modulus dividing cell **210** not only can couple to a single programmable frequency divider, but can also couple to more than one programmable frequency dividers.

FIG. **5** is a block diagram of an exemplary programmable integer frequency divider **110** in FIG. **1**. In comparison to FIG. **3**, the only difference is that zipper frequency divider **310** in programmable integer frequency divider **110** is coupled to two integer frequency division cells **520** and **530**, and divisor switching signal S_{DS} is coupled to two integer frequency dividers **520** and **530**.

Integer frequency divider **520** is coupled to output signal $So1$ generated by zipper frequency divider **310**, then divides the frequency of output signal $So1$ by integer divisor N_{D2} to generate the second output signal $So2$. Further, integer frequency divider **520** utilizes divisor switching signal S_{DS} to change integer divisor N_{D2} . Similarly, integer frequency divider **530** receives the second output signal $So2$ generated by integer frequency divider **520**, and divides the second output signal $So2$ by integer divisor N_{D3} to generate output signal S_{OUT} .

Integer frequency divider **520** may be a multi-mode programmable frequency divider receiving divisor switching signal S_{DS} and the second divisor control signals, e.g., $S_CTRL_2(0)$ to $S_CTRL_2(P-1)$ to change integer divisor N_{D2} . Further, integer frequency divider **530** may also be a multi-mode programmable frequency divider receiving at least one third divisor control signals, e.g., $S_CTRL_3(0)$ to $S_CTRL_3(Q-1)$ to change integer divisor N_{D3} .

In one embodiment, when divisor switching signal S_{DS} is the first or the second level, accordingly, integer divisor N_{D2} of integer frequency divider **520** is N_{D21} or N_{D22} , and integer divisor N_{D3} of integer frequency divider **530** is N_{D31} or N_{D32} . When divisor switching signal S_{DS} is the first level (high level), the overall divisor of zipper frequency divider **310**, integer frequency dividers **520** and **530** is $N_{S1}=N1^N\times N_{D21}\times N_{D31}$. When divisor switching signal S_{DS} is the second level (low level), the overall divisor of zipper frequency divider

310, integer frequency dividers **520** and **530** is $N_{S2} = N1^N \times N_{D21} \times N_{D31} + (2^{N+P+Q-1} \times DS_{N+P+Q-1} + 2^{N+P+Q-2} \times DS_{N+P+Q-2} + \dots + 2^0 \times DS_0)$.

Thus, when fractional number switch **120** sets the fractional number to be $1/N_P$, and the pulse width of divisor switching signal S_DS equals to that of output signal S_OUT , $Z = N_{S1} \times (N_P - 1) / N_P + N_{S2} / N_P = N1^N \times N_{D21} \times N_{D31} + (2^{N+P+Q-1} \times DS_{N+P+Q-1} + 2^{N+P+Q-2} \times DS_{N+P+Q-2} + \dots + 2^0 \times DS_0) / N_P$, where DS_0 to $DS_{N+P+Q-1}$ are determined by $S_CTRL(0)$ to $S_CTRL(N-1)$, $S_CTRL_2(0)$ to $S_CTRL_2(P-1)$, and $S_CTRL_3(0)$ to $S_CTRL_3(Q-1)$.

Generally speaking, if $N_P = 2^M$, by utilizing programmable integer frequency divider **110** in the embodiment, divisor Z of the programmable integer and fractional frequency divider is represented by:

$$Z = N1^N \times N_{D21} \times N_{D31} + 2^{-M} \times DZ_0 + 2^{-(M-1)} \times DZ_1 + \dots + 2^{N+P+Q-M-2} \times DZ_{N+P+Q-2} + 2^{N+P+Q-M-1} \times DZ_{N+P+Q-1}$$

The difference between FIG. 5 and FIG. 3 is that the start integer is changed from $N1^N$ to $N1^N \times N_{D21} \times N_{D31}$. In order to obtain divisor Z , the predetermined divisor N_P and signal levels of DZ_0 to $DZ_{N+P+Q-1}$ are required, where DZ_0 to $DZ_{N+P+Q-1}$ are determined by $S_CTRL(0)$ to $S_CTRL(N-1)$, $S_CTRL_2(0)$ to $S_CTRL_2(P-1)$, and $S_CTRL_3(0)$ to $S_CTRL_3(Q-1)$.

In a similar way, the zipper divider can couple to any number of integer frequency dividers, wherein divisor switching signal S_DS controls the divisors of any number of the integer frequency dividers.

FIG. 4 is a block diagram of integer frequency dividers **520** or **530**. As shown in FIG. 4, the difference between integer frequency divider **520** and integer frequency divider **320** is that for integer frequency divider **520**, logic circuit **424** receives divisor switching signal S_DS and $S_CTRL_2(0)$ to $S_CTRL_2(P-1)$ to change integer divisor N_{D2} . In the preferred embodiment, integer frequency divider **520** further comprises a phase adjusting circuit synchronizing divisor switching signal S_DS1 and output signal $So1$ generated by zipper frequency divider **310**. The difference between integer frequency divider **530** and **320** is that integer frequency divider **530** receives $S_CTRL_3(0)$ to $S_CTRL_3(Q-1)$ to change integer divisor N_{D3} .

Note integer frequency divider **320** in FIG. 4 is only an example; a programmable integer frequency divider with a pulse/swallow counter may also be used in replacement of integer frequency divider **320**. Since integer frequency divider with a pulse/swallow counter has the advantage of appropriate divisor range, the efficiency is degraded when combined with a zipper divider, thus integer frequency divider with fraction division functionality is a preferred choice.

FIG. 6a is a block diagram of another exemplary programmable integer and fraction frequency divider **100** in FIG. 1. As shown in FIG. 6a, fractional number switch **620a** is added in between the output of swallow counter **630a** and the input control terminal of dual-modulus frequency divider **610a**. The operating principle of fractional number switch **620a** was provided previously and the description thereof is omitted here for brevity.

Divisor Z of an integer frequency divider with a pulse/swallow counter may be represented by $Z = P \times N1 + S$, where $N1$ and $(N1+1)$ are the divisors generated by dual-modulus frequency divider **610a** according to the divisor switching signal, S is an integer value of swallow counter **630a**, and P is an integer value of **640a**.

In one embodiment, when divisor switching signal S_DS is the first or second levels, the divisor of output signal S_OUT of **640a** is integers N_{S1} or N_{S2} . When divisor switching signal S_DS is the first level (high level), the overall divisor N_{S1} of programmable integer and fraction frequency divider **100** is $N_{S1} = P \times N1$. When divisor switching signal S_DS is the second level (low level), the overall divisor N_{S2} of programmable integer and fraction frequency divider **100** is $N_{S2} = P \times N1 + S$. Therefore, when fractional number switch **620a** sets the fractional number thereof as $1/N_P$, and the pulse width of divisor switching signal S_DS equals to that of swallow counter **630a**, $Z = N_{S1} \times (N_P - 1) / N_P + N_{S2} / N_P = P \times N1 + S / N_P$.

Note the integer frequency divider of the pulse/swallow counter has to satisfy $P \geq N1$ and $P \geq S$, thus S can be insufficient when serving as a fractional frequency divider, thus, FIGS. 6b and 6c are utilized instead. When reset signals of main and auxiliary swallow counters are synchronized, at least one auxiliary feedback circuit (swallow counter and fractional number switch) is required, the divisor of programmable integer and fraction frequency divider **100** is $Z = P \times N1 + S_1 / N_{P1} + \dots + S_N / N_{PN}$, where $N_{P1} > \dots > N_{PN}$ and $P \geq S_1 \dots S_N$ (as shown in FIG. 6b). When reset signals of main and auxiliary swallow counters differ by a pulse width of the output signal of the dual-modulus divider, only one auxiliary feedback circuit is required, the divisor of programmable integer and fraction frequency divider **100** is $Z = P \times N1 + S_1 / N_{P1} + S_2 / N_{P2}$, where $N_{P1} > N_{P2}$ and $P \geq S_1$ and S_2 (as shown in FIG. 6c).

In general, if $N_P = 2^M$, when utilizing programmable integer frequency divider **110** with the pulse/swallow counter in the embodiment, divisor Z of programmable integer and fractional frequency divider is represented by:

$$Z = P \times N1 + 2^{-M1} \times S_1 + \dots + 2^{-MN} \times S_N$$

Where $M1 > \dots > MN$, and S_1 to S_N are all less or equal to P .

FIG. 7 is a block diagram of an exemplary fractional number switch **120**. As shown in FIG. 7, fractional number switch **120** comprises a counter **710** and a phase adaptor **720**. The counter **710** receives the output signal S_OUT , calculates a pulse count of the output signal S_OUT , and generates divisor switching signal S_DS according to the pulse count. The phase adaptor **720** adjusts the phase of divisor switching signal S_DS . When fractional number switch **120** is incorporated into the programmable integer frequency dividers in FIGS. 2, 3, 5, and 6, the phases of divisor switching signal S_DS is adjusted such that the phases of divisor switching signal S_DS is synchronized with the output signal of a front divider. Taking programmable integer frequency divider **110** in FIG. 2 as an example, the front divider may be, for example, dividing cell **210(2)** when incorporating with a zipper divider, and dividing cell **610** when incorporating with a pulse/swallow divider.

Note the programmable integer and fractional frequency divider can comprise not only one single divisor switch, but also more than one divisor switches. Those with ordinary skill in the art can make modification to the circuitry wherever appropriate.

While the invention has been described by way of example and in terms of preferred embodiment, it is to be understood that the invention is not limited thereto. To the contrary, it is intended to cover various modifications and similar arrangements (as would be apparent to those skilled in the art). Therefore, the scope of the appended claims should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.

What is claimed is:

1. A programmable integer and fractional frequency divider, dividing a frequency of an input signal by a first divisor to generate an output signal, wherein the first divisor is an integer or a fraction, and the programmable integer and fractional frequency divider comprises:

a programmable integer frequency divider, dividing the frequency of the input signal by a second divisor to generate the output signal, wherein the second divisor is set to be first or second integers according to a divisor switching signal; and

a fractional number switch, calculating a pulse count of the output signal, and generating the divisor switching signal to switch from the first integer to the second integer when the pulse count of the output signal equals to a predetermined pulse count, wherein the predetermined pulse count is determined by a fractional part of the first divisor, and the fractional number switch receives at least a fractional divisor control signal to change the predetermined pulse count, thereby changing the fractional part of the first divisor.

2. The programmable integer and fractional frequency divider of claim 1, wherein the programmable integer frequency divider further receives at least one divisor control signal to select the first or the second integers.

3. The programmable integer and fractional frequency divider of claim 1, wherein the predetermined pulse count is set by the ratio of a pulse width of the output signal of the programmable integer and fractional frequency divider to a pulse width of the divisor switching signal.

4. The programmable integer and fractional frequency divider of claim 2, wherein the first integer is an integer irrelevant to the divisor control signal, and the second integer is set as $N1^N + (N1^{N-1} \times DS_{N-1} + N1^{N-2} \times N1_{N-2} + \dots + N1^0 \times DS_0)$ according to the divisor control signal, DS_{N-1} to DS_0 are determined as 0 or 1 according to the divisor control signal, and N and N1 are third and fourth integers.

5. The programmable integer and fractional frequency divider of claim 1, wherein the programmable integer frequency divider comprises a zipper frequency divider comprising at least one dual-modulus divider coupled in series, divisors of each dual-modulus divider receives a divisor control signal and a mode signal to set third and fourth integers respectively, and the divisor switching signal serves as the mode signal for the last dual-modulus divider.

6. The programmable integer and fractional frequency divider of claim 5, wherein the zipper frequency divider receives the input signal to divide the frequency thereof by the second integer to generate an input signal of the fractional number switch, the first divisor is determined according to the divisor control signal, and the mode signal of each dual-modulus divider and the predetermined pulse count.

7. The programmable integer and fractional frequency divider of claim 6, wherein:

$Z = N1^N + N^{-M} \times DZ_0 + N1^{-(M-1)} \times DZ_1 + \dots + N1^{N-M-2} \times DZ_{N-2} + N1^{N-M-1} \times DZ_{N-1}$, Z is the first divisor, N is the number of the dual-modulus divider, N1 is the third integer, M is an integer, $(N1)^M/X$ is the predetermined pulse count, and X is the divisor switching signal such that a pulse width of the switching signal is equivalent to X times of a pulse width of the output signal, and DZ_0 to DZ_{N-1} are 0 or 1; and

the divisor control signal S_CTRL(k) level of each dual-modulus divider is set by first and second level according to DZ_k .

8. The programmable integer and fractional frequency divider of claim 7, wherein the dual-modulus divider com-

prising a divide-by-2/3 cell or a mode I/O control terminal coupled to a logical circuit to change the first divisor to be:

$$Z = N1^N + 2^{-M} \times DZ_0 + 2^{-(M-1)} \times DZ_1 + \dots + 2^{N-M-2} \times DZ_{N-2} + 2^{N-M-1} \times DZ_{N-1}, \text{ where the predetermined pulse count is } 2^M/X.$$

9. The programmable integer and fractional frequency divider of claim 8, wherein the programmable integer frequency divider further comprises a second integer frequency divider, the zipper frequency divider receives the input signal, and the second integer frequency divider divides the output signal of the zipper frequency divider by a fifth integer to produce the output signal of the programmable integer frequency divider.

10. The programmable integer and fractional frequency divider of claim 9, wherein the first divisor is determined by the divisor control signal of each dual-modulus divider, the fifth integer, and the predetermined pulse count.

11. The programmable integer and fractional frequency divider of claim 10, wherein:

$$Z = N1^N \times N_{D2} + 2^{-M} \times DZ_0 + 2^{-(M-1)} \times DZ_1 + \dots + 2^{N-M-2} \times DZ_{N-2} + 2^{N-M-1} \times DZ_{N-1},$$

Z is the first divisor, N is the number of the dual-modulus divider, N1 is the third integer, N_{D2} is the fifth integer, M is an integer, $2^M/X$ is the predetermined pulse count; and

X is the divisor switching signal such that a pulse width of the switching signal is equivalent to X times of a pulse width of the output signal, and DZ_0 to DZ_{N-1} are 0 or 1; and

The divisor control signal S_CTRL(k) of each dual-modulus divider is set to be the first or second levels depending on DZ_k being 1 or 0.

12. The programmable integer and fractional frequency divider of claim 9, wherein the second integer frequency divider is a multi-mode frequency divider receiving at least a second divisor control signal to change the fifth integer.

13. The programmable integer and fractional frequency divider of claim 12, wherein the second integer frequency divider comprises:

a third integer frequency divider, dividing the frequency of the output signal of the zipper frequency divider by a sixth integer to provide phase output signals with different phases;

a phase switch, receiving a phase conversion data to determine the output signal corresponding to the phase output signal;

a memory, storing the phase conversion data with more than 2 divisors, each corresponding to different sixth integers; and

a logic circuit, receiving at least one sixth integer control signal and divisor switching signal, generating a memory address according to the at least one sixth integer control signal and divisor switching signal to instruct the memory at the memory address to provide the phase conversion data to a phase control terminal of the phase switch.

14. The programmable integer and fractional frequency divider of claim 6, wherein the integer frequency divider further comprises second and third integer frequency dividers, the zipper frequency divider receives the input signal, the second integer frequency divider divides the output of the zipper frequency divider by a third divisor, and receives the divisor switch signal to change the third divisor to fifth or sixth integers, and the third integer frequency divider divides the output of the second integer frequency divider by a seventh integer to generate the output signal of the integer divider.

11

15. The programmable integer and fractional frequency divider of claim 14, wherein the first divisor is determined by the divisor control signal of each dual-modulus divider, the fifth, sixth, and seventh integers, and the predetermined pulse count.

16. The programmable integer and fractional frequency divider of claim 15, wherein:

$$Z = N1^N \times (N_{D22} - N_{D21}) \times N_{D3} + 2^{-M} \times DZ_0 + 2^{-(M-1)} \times$$

$DZ_1 + \dots + 2^{N-M-2} \times DZ_{N-2} + 2^{N-M-1} \times DZ_{N-1}$. N is the number of the dual-modulus divider, N1 is the third integer, M is an integer, N_{D21} is the fifth integer, N_{D22} is the sixth integer, N_{D3} is the seventh integer, $2^M/X$ is the predetermined pulse count; and

X is the divisor switching signal such that a pulse width of the switching signal is equivalent to X times of a pulse width of the output signal,

DZ_0 to DZ_{N-1} are 0 or 1 satisfying $(N1^N \times (N_{D22} - N_{D21}) \times N_{D3} + 2^0 \times DS_0 + 2^1 \times DS_1 + \dots + 2^{N-1} \times DS_{N-1}) = (N1^N \times N_{D21} \times N_{D3} + 2^0 \times DZ_0 + 2^1 \times DZ_1 + \dots + 2^{N+Q-2} \times DZ_{N+Q-2} + 2^{N+Q-1} \times DZ_{N+Q-1})$; and

12

The divisor control signal S_CTRL(k) of each dual-modulus divider and the second integer frequency divider is set to be the first or second levels depending on DZ_k being 1 or 0, and Q is the number of divisor control terminals of the second integer frequency divider.

17. The programmable integer and fractional frequency divider of claim 14, wherein the second integer frequency divider is a multi-modulus divider receiving at least one second divisor control signal to change the sixth integer, and the third integer frequency divider is a multi-modulus divider receiving at least one third divisor control signal to change the seventh integer.

18. The programmable integer and fractional frequency divider of claim 1, wherein the fractional number switch comprises:

a phase adjusting circuit synchronizing the divisor switching signal of the fractional number switch and the output signal of the programmable integer frequency divider.

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